1 Physics Motivation - Experiment Overview

This section contains a summary of the physics motivation for each of the individual contributions contained in this package, with references to the already approved or conditionally approved proposals, extensions of already approved experiments to 6 GeV, and the list of new proposals.

1.1 Introduction

For decades electron scattering has been utilized as the major tool for probing the structure of nucleons in inclusive reactions. Unpolarized and polarized quark and gluon structure functions have been studied in these experiments over many years. Studies of exclusive reactions are needed to understand the dynamics of production processes through resonance decays, quark fragmentation, or hard processes. Unfortunately, little is known about exclusive hadron production in inelastic electron scattering. One of the main reasons for this lack of knowledge has been technical in nature. The low production rates and the need to cover a large phase space in the final state, made it necessary to employ large-acceptance detectors with sufficient resolution to isolate exclusive channels. Furthermore, these detectors had to operate in an electron beam environment with high luminosity. These requirements could not be met at electron accelerators with low-duty cycles. As a consequence, only the simplest reactions were studied, often in a very limited kinematical regime, and most often with insufficient statistics.

The CLAS detector, operated at the CEBAF CW electron machine for the past 18 months, has quickly proven that these technical obstacles have been overcome. Large acceptance, combined with good resolution and particle identification capabilities, and the ability to operate at luminosities of 10^{34} cm^{-2}s^{-1} in an electron beam environment, have opened up many new avenues leading to detailed investigations of hadron structure in exclusive reactions.

This proposal package has been developed based on the experience of operating CLAS for the study of exclusive reactions at lower energies and momentum transfers. Moreover, a short test run at 5.56 GeV was carried out and analyzed. The results of this run give us full confidence that the performance of CLAS is adequate to to carry out the program put forward in this proposal package.

On the theoretical side, it is now becoming more apparent that the elementary quark and gluon fields are likely not the relevant, or at the least, not the dominant degrees of freedom for many exclusive reactions in the energy domain of CEBAF. Constituent quarks, gluon flux tubes, and pions may be much more relevant for the interpretation of the data. Theoretical models based on these degrees of freedom have been developed in many areas, such as N^*-resonance transitions, the production of strange mesons in hyperon excitations, and the production of gluonic mesons ("hybrids"), and are able to make predictions in the large kinematic regime that is currently covered at CEBAF and beyond.

Having said that, we hasten to stress that new theoretical developments during the past few years have shown that there are windows available for the study of exclusive reactions at high momentum transfer. These bear on the interpretation in terms of elementary parton fields. A theoretical framework has emerged for the study of a new set of generalized parton distribution functions, the "skewed parton distributions" (SPDs), that can only be accessed in deeply virtual exclusive reactions at sufficiently high momentum transfer, and in the deep-

Physics Category	Exp. #	Sect. #	Reaction $ep \rightarrow$	PAC Status	Main Physics Focuses
Deeply Virtual Meson Production	1	4.3	$e'p\rho$ $e'p\omega$	E98-107 (C)	-Study transition to asymptotic regime to probe unpolarized SPDs.
	2	4.4	$e'n\pi^+$	New	-Study transition to asymptotic regime to probe polarized SPDs. -Measure cross sections for Q^2 <5.5 (GeV/c)^2 and σ_L,σ_T response for Q^2 <3.2 (GeV/c)^2
			$e'p\pi^0$ $e'p\eta$	New	-Measure cross sections for Q^2 <5.5 (GeV/c)^2
N^* Physics at High Q^2	3	5.3	$e'p\pi^0$	E91-002 (E)	-Study $\Delta(1232)$ and $S_{11}(1535)$ up to Q^2 <5.5 (GeV/c)^2
			$e'p\eta$		-Study transition regime between CQM and pQCD
			$e'n\pi^+$		-Study I=1/2 resonance excitations e.g. $D_{13}(1510)$ and $F_{15}(1680)$
	4	5.4	$e'p\pi^+\pi^-$	E93-006 (E)	-Study higher mass resonances e.g. $S_{31}(1620)$ and $D_{33}(1700)$ -Study transition to [70,1$^-$] supermultiplet at high Q^2 -Test validity of CQM at high Q^2
	5	5.5	$e'p\eta'^{(\dagger)}$	New	-Study resonances above 1.9 GeV and search for missing resonances -Study quark content of η' and $U_A(1)$ anomaly
Strangeness Production	6	6	$e'KY$	E89-043 (E) E93-030 (E) E95-003 (E) E99-006 (E)	-Measure cross sections, single and double polarization observables -Search for strange decays of missing N^* resonances -Study reaction mechanism
	7	7	$e'p\phi$	E93-022 (E)	-Test QCD-predicted shrinkage of longitudinal photons with Q^2
Exotic Meson	8	8	$e'\pi\eta X^{(\dagger)}$ $e'\pi\eta' X^{(\dagger)}$	E94-119 (C)	-Search for J^{PC}=1^{-+} exotic mesons
Forward Pseudoscalar Meson Production	9	9	$e'n\pi^+$ $e'p\pi^0$ $e'K^+\Lambda$	New	-Study transition to asymptotic regime -Extract structure functions σ_T, σ_L, σ_{TT}, and σ_{TL}

Table 1: Summary of all experiments in this package. Those reactions highlighted with a (†) require CLAS operation at $B = -50\%B_0$. All other will run CLAS at $B = 90\%B_0$. In the *PAC Status* column, (C) indicates experiments that have been conditionally approved by PAC for running at 6 GeV and (E) indicates an extension of a PAC-approved lower-energy experiment.

inelastic regime. Rapid theoretical development in this new area of electromagnetic physics is underway, and needs to be nurtured by the prospect of data coming from CLAS in a timely fashion. While it is quite clear that 6 GeV will not allow us to fully reach the asymptotic regime, mapping out the transition into this regime will be of great importance as corrections due to higher-twist contributions can be evaluated. Evaluating these contributions is now becoming the main focus of the theoretical activity in this area.

In the following sections we present brief motivations and experimental summaries related to the nine individual contributions to the package. Table 1 gives an overview of the full proposal package and the main physics goals for each of the contributions.

1.2 Deeply Virtual Meson Electroproduction

The possibility of operating JLab at high luminosity and momentum transfers greater than a few (GeV/c)^2 has influenced the theoretical community into making a concerted effort to deal with exclusive reactions in this kinematic regime. Very recently, several theoretical groups have made ground-breaking progress. The techniques involve a combination of soft and hard physics. It was proven, for the case of longitudinal photons, that at high enough Q^2, exclusive reactions can be factorized into parts containing the soft and hard physics involved. For non-longitudinal cross sections, the transverse higher-twist mechanisms would have to be modeled.

The hard physics can be treated separately by pQCD techniques, and the soft physics of the hadronic states can be parameterized in terms of skewed parton distribution functions. These SPDs are generalizations of the deep-inelastic scattering (DIS) distribution functions $q(x)$ and $\Delta q(x)$ that are accessed in non-polarized and polarized inclusive DIS electron experiments, respectively. For the prototype deeply virtual Compton scattering, the SPDs are said to be *diagonal*, while for single-meson production, the SPDs are of a different, newly accessible, *non-diagonal* type. Vector and pseudoscalar meson production are complementary in that vector meson production is sensitive to the unpolarized quark distribution functions, while pseudoscalar meson production, which is proposed here, is sensitive to the polarized structure functions relating to the nucleon spin distribution.

This proposal is to measure pseudoscalar meson production cross sections, and is complementary to experiment E98-107, which will measure vector meson production. The intent is to obtain cross sections at W above the resonance region at the highest Q^2 possible. For a 6 GeV electron beam, we estimate the maximum Q^2 attainable for π^0 production is about 5.5 (GeV/c)^2, and for η production, is somewhat lower. The momentum transfer t will be in the range t_{min} up to several (GeV/c)^2. The connection with the DIS structure functions are closest near t_{min}. For $n\pi^+$ production, the focus is on isolating the longitudinal part of the cross section. By combining measurements at 2 or 3 different energies in a Rosenbluth separation of the cross sections, we can reach a maximum Q^2 of about 3 (GeV/c)^2. Moreover, the experiment would produce high quality cross section data for $n\pi^+$ with Q^2 up to 5.5 (GeV/c)^2 and a maximum $-t$ of 6 (GeV/c)^2. No such data has been measured before.

It is expected that the mechanisms that will be accessible at potential JLab energies, and moderate Bjorken x_B, are those involving quark currents, as opposed to those involving gluonic currents that can only be accessed at much higher energies. Specific to pseudoscalar mesons, there is currently considerable theoretical activity to calculate the possible experimental manifestations. Among the important questions that need to be addressed is how to handle the hard kernel. The simplest approach would be to treat it in terms of valence